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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003903283 for a patent by H.A.C. TECHNOLOGIES PTY LTD as filed on 26 June 2003.



WITNESS my hand this  
Second day of July 2004

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AUSTRALIA  
Patents Act 1990

**PROVISIONAL SPECIFICATION**

**Applicant:**

H.A.C. TECHNOLOGIES PTY LTD

**Invention Title:**

REFORMATE ASSISTED COMBUSTION

The invention is described in the following statement:

## REFORMATE ASSISTED COMBUSTION

The present invention relates generally to the production of gas, particularly gas that can be used as a fuel or as one component of a fuel or in combination with a fuel. In particular, the present invention relates to a method and apparatus for producing hydrogen or a hydrogen-containing gas together with other components, typically gaseous components, for use as a fuel, fuel component or in combination with a fuel in an engine. More particularly, the present invention relates to a method and apparatus of more efficiently producing a hydrogen-containing gas for use as a fuel or fuel additive, or in combination with a fuel for an engine, such as for example, as part of the air supply for an engine, particularly a combustion engine, such as a compression engine, including a diesel engine or similar. Even more particularly, the present invention relates to the use of a hydrogen generator, such as for example, a reformer for producing a reformat gas from heated steam or from heating fuels and air or other gases with steam, in which the reformat gas contains materials other than hydrogen, such as for example, oxygen, nitrogen, water vapour, carbon monoxide, carbon dioxide, carbon-containing materials or gases or the like, for use in combination with air as an additive to fuel for use in a compression engine, particularly an engine using hydrogen-assisted combustion, such as a diesel engine.

The present invention finds particular application as a method and apparatus for producing a hydrogen-containing gaseous blend and a method of using the gaseous blend as a fuel component which is added to the air stream being introduced into a diesel engine for hydrogen-assisted combustion or reformat assisted combustion to promote more efficient combustion. The method and apparatus of the present invention allows hydrogen-containing gas to be produced more efficiently at lower cost, and when used as

a fuel allows the problems associated with hydrogen-assisted combustion, such as for example, damaging pre-ignition or excessive cylinder pressures to be avoided, by being able to use a gas which contains other materials in addition to the hydrogen, thereby obviating the previously used expensive purification processes that were required to remove almost all of non-hydrogen gas components from the material being produced by the hydrogen generator, before it could be used in applications such as for example exhaust catalytic treatments, fuel cells or similar.

Although the present invention will be described with reference to one form of a hydrogen reformer, producing a reformat gas containing hydrogen together with other gaseous components and the use of this gas as a fuel component in diesel engines, it is to be noted that the present invention is not restricted to the described embodiment, but rather, the scope of the present invention is more extensive so as to include other means of producing hydrogen, the production of gases containing hydrogen other than the reformat gas, the use of various gaseous mixtures or blends in applications other than engines, and different embodiments of combining the fuel components together and introducing the various gaseous combinations into engines.

It is known to use hydrogen as a fuel additive in some types of engines, most notably internal combustion engines or similar engines, such as diesels, as part of the fuel system and/or air supply system. The use of hydrogen is termed hydrogen-assisted combustion. However, it appears as though only minimal investigations have been conducted regarding the various aspects of hydrogen-assisted combustion in compression ignition engines, such as for example, diesel engines and the like. One reason for this is that there are a number of serious problems associated with hydrogen-assisted combustion. It was thought that if hydrogen gas could be added to the fuel

system and/or air supply system of diesel engines, the presence of the hydrogen as part of the overall fuel composition would increase the power and efficiency of such engines by increasing the efficiency of combustion of the fuel in such engines, such as for example, by having increased burning efficiency to produce greater power or the like. However, introducing hydrogen as a significant component into the fuel composition resulted in damaging pre-ignition and the development of excessive cylinder pressure.

Up until now, no one had thought of using a hydrogen gas blend or mixture and particularly no one had thought of using high volume reformers to produce hydrogen for introduction into the engine without purification because reformers of this type were developed in fuel cell technology and were not connected to inlets or other fuel, air or the like inlets in order to reduce fuel consumption. Their primary use was to use the impure form of the gases to preheat engines and treat exhausts, but not to use them with air, and certainly not to use it with hydrogen-assisted combustion.

Surprisingly, it has now been discovered that at least some compression engines are able to use a gas which is less pure in hydrogen content that results in increased combustion efficiency and increased power being developed by the engine. Also, in some cases, the exhaust emissions have improved as well. Therefore, rather than removing the contaminating or impure components from the hydrogen produced by the hydrogen generator at high cost as previously required, the present inventors have been able to use hydrogen combined with other components from the hydrogen generator as an additive to the fuel supply of diesel engines without any observable reduction in efficiency of operation or power generation within the engine.

Another problem of existing hydrogen-assisted combustion techniques is that various other components

were required to be added to the hydrogen in order to overcome the problems of hydrogen-assisted combustion within an engine and also these other components needed to be added separately to the engine in order to control  
5 precisely the amounts of each individual component. Thus, a separate feed or supply line to the engine was needed for each of the various components, such as for example, separate supply lines or feed lines for substantially pure hydrogen, water, air and fuel were required. Metering and  
10 controlling the introduction of predetermined amounts of each of the components required sophisticated monitoring equipment, sensors, injecting equipment and the like to ensure that the correct amounts and ratios of all of the components were introduced into the engine, and that the  
15 components were adequately mixed together in the correct proportions before actual combustion within the engine. Thus, there was a degree of complexity associated with existing hydrogen-assisted combustion techniques and equipment. Accordingly, there is a need to reduce the  
20 complexity of introducing separate materials in separate feed lines, and combining the materials in the correct ratios and in the correct manner. The present invention sets out to provide a method and apparatus for having a single feed of a hydrogen gas, blend or mixture requiring  
25 a single feed line or input only.

Therefore, it is an aim of the present invention to provide a method and apparatus for generating a hydrogen-containing gas in combination with other materials and a method and apparatus for using the hydrogen-containing gas  
30 as a fuel component in compression engines without the need to remove other unwanted components from the hydrogen gas prior to its use as the fuel. Further, it is another aim of the present invention to provide a method and apparatus that provides the correct amount and ratio of  
35 components in the gaseous blend or mixture by adjusting the operating conditions of the hydrogen gas mixture or blend generator.

According to one aspect of the present invention, there is provided a method of using a hydrogen-containing gas as a fuel, a component of a fuel, a fuel additive or an additive to air for mixing with a fuel in a compression engine, in which the hydrogen-containing gas also contains other products from the hydrogen generation process, including the steps of producing the hydrogen-containing gas, blend or mix, introducing the blend to a compression engine as one component of the fuel, and combusting the fuel to produce power in the engine, wherein the relative amounts of the components of the gas blend or mixture are selected in accordance with the requirements of hydrogen-assisted combustion of the engine.

According to another aspect of the present invention, there is provided an apparatus for producing a hydrogen-containing gas blend or mix, including the steps of producing hydrogen in combination with other materials, wherein the hydrogen-containing gas blend or mix includes hydrogen and the other materials in which the relative amounts of the hydrogen and other materials are in predetermined amounts with respect to each other in accordance with the requirements of hydrogen-assisted combustion of the engine.

According to another aspect of the present invention, there is provided a method of operating a hydrogen generating apparatus to produce a hydrogen-containing gas blend or mixture comprising hydrogen and at least one other component suitable for use as a fuel, a fuel component, an additive or similar, including the steps of adjusting operating parameters of the hydrogen generating apparatus to provide a preselected composition of the gas blend or mixture in which the respective amounts of the hydrogen and other component or components are in accordance with requirements of an engine to which the gas blend or mixture is provided or supplied in order to facilitate hydrogen-assisted combustion of the engine,

thereby increasing the efficiency and/or performance of the engine.

According to another aspect of the present invention, there is provided a fuel for hydrogen-assisted combustion in an engine comprising hydrogen in combination with one or more other materials in which the relative amounts of the hydrogen to the other material or materials is selected in accordance with the requirements of the engine.

According to another aspect of the present invention, there is provided a hydrogen-containing gas blend or mix containing one or more components in which the relative amounts of the hydrogen to the other component or components is in accordance with the requirements for hydrogen-assisted combustion within an engine.

Typically, the hydrogen generator useful in the present invention generates hydrogen in combination with other materials. Typically, the hydrogen generator is an electrolysis apparatus, a fuel cell, a reformer, a cold fusion apparatus or the like, including any apparatus for making hydrogen. Preferably, the hydrogen generator is a reformer in which steam is used to heat a fuel as it passes over a catalyst. The fuel and steam are cracked. The reformers generally reform a hydrocarbon fuel to hydrogen gas with the aid of steam. Typically, the hydrogen is produced along with oxygen, nitrogen, water, ethanol, carbon dioxide, carbon monoxide, hydrocarbons such as methanol, methane or the like.

Typically, the hydrocarbon material is a paraffin or paraffin-like hydrocarbon-containing saturated bonds. More typically, the hydrocarbon is selected from  $C_1$ - $C_{20}$ , preferably from  $C_2$ - $C_{12}$ , more preferably  $C_4$ - $C_{10}$ , and most preferably  $C_8$ , including mixtures and combinations of one or more such materials.

Typically, the methanol, methane or the like is a byproduct from the fuel used in the reformer to produce hydrogen, such as for example, being derived from the



original reformer-based fuel, such as diesel, petrol, canola oil or the like.

Typically, the gaseous blend or mixture produced by the hydrogen generator contains from 0-50% by volume of hydrogen, preferably 30-40% by volume, and preferably 35-38% by volume hydrogen. Typically, there is from 0-25% by volume of carbon monoxide, preferably 3-5% by volume, and preferably 4-5% by volume carbon monoxide. Even more typically, the amount of hydrocarbon material is from 0-5% by volume, typically 1-4% by volume, and preferably 2-3% by volume. Typically, the amount of carbon dioxide produced is from 0-25% by volume, preferably 5-15% by volume, and preferably 3-10% by volume. It is to be noted that the balance of any gaseous blend or mixture is made up of nitrogen.

Another aspect of the present invention is the ability to predetermine the ratio of individual components in the gaseous blend or mixture being produced by the hydrogen generator. Depending upon the requirements of the engine, the hydrogen generator can be operated at selectively adjustable parameters in order to provide the optimal amounts and ratio of the various components of the gaseous blend or mixture to achieve maximum efficiencies of the operation of the engine, depending upon a number of factors of the engine.

Typical parameters of the materials being fed to the engine are the gas flows or gas velocities of the various components and the overall composition of the mixture of components, the temperature at which the hydrogen generator is operated, the pressure at which the hydrogen generator is operated, the velocity of gas being passed through, produced by or formed in the generator, the catalyst being used in the generator, the amount of exposure of the reactants to the catalyst or the like.

It is to be noted that the operating conditions of the hydrogen generator are adjustable so that the production of certain components can be minimised or

prevented by operating the system within set amounts. However, it is to be noted also that the production of other components can be optimised.

5 Typical operating conditions of the reformer which catalytically decomposes or cracks heated steam to produce hydrogen and oxygen include the following. The reformer can be operated at a temperature of from 100°C-1,000°C, typically from 200°C-900°C, preferably from 220°C-800°C.

10 Typically, the pressure of operation of the reformer is from 1-5 bar, typically from 1-3 bar and preferably at about 2 bar.

Typically, the reformer can produce from about 1,000-50,000 litre per hour. Typical catalysts include platinum, nickel or any other suitable catalyst for  
15 catalysing the reforming of hydrogen from heated steam.

The present invention will now be described by way of example with reference to the accompanying drawing, in which:

Figure 1 is a schematic view of one form of the gas  
20 blend supply system of the present invention;

Figure 2 is a schematic view of another form of the gas blend supply system of the present invention.

In Figure 1 is shown schematically one form of a gas supply system in accordance with the present invention, generally denoted as 2. This form includes a hydrogen  
25 generator, for producing hydrogen-containing gas. One example of the hydrogen generator is a reformer 10 for producing a reformat gas which contains hydrogen as one component. In one embodiment, the reformer 10, which is  
30 sometimes known as a fuel processor, takes the form of an open grid of metal through which a stream of heated steam 12 is passed. The metal from which the grid can be made is a suitable catalyst, such as platinum or nickel or the metal may be coated with a coating of a suitable  
35 catalysing material, such as a nickel or platinum-containing compound, or a compound containing both nickel and platinum, or any other suitable catalytic material.

Heat is applied to the incoming heated steam 12 optionally in combination with other gases, fuel or the like, in the proximity of the catalytic metal surface so as to catalytically decompose the steam to form a hydrogen-  
5 containing gas and other materials. In one embodiment, a supply of air 14 is introduced into reformer 10 as is a supply of reformer fuel 16. Typically, the reformer may include a plasma device or plasma arc or similar for decomposing or cracking the steam and/or other gases  
10 and/or fuel into hydrogen and the other components.

Along with hydrogen being produced in the hydrogen generator, other gaseous components can also be produced.

Typical examples of other materials produced in the gaseous mixture or blend include nitrogen, carbon dioxide,  
15 carbon monoxide, methane, ethanol, hydrocarbons or the like.

The gaseous mix or blend 18 is discharged from the reformer 10 at a temperature of about 600°C, whereupon it is passed through a first or main heat exchanger 20, where  
20 heat is extracted so as to reduce the temperature of the gas mixture or blend to about 200°C. Optionally, the gas blend is passed to a second or auxiliary heat exchanger 22 where further heat is extracted so as to reduce the temperature of the gas blend even further to below about  
25 100°C, preferably below about 100°C, more preferably below about 50°C. A condensate stream 24 formed from the cooling of the gas blend is returned to a water supply vessel 26 or similar which in turn is passed through a third heat exchanger 28 to heat the water concentrate and fresh water  
30 mixture 30 to form steam for supply to the reformer 10 as the steam supply 12 to assist in the efficiency of operation of the hydrogen generator.

The gas blend or mix 18 now at 200°C is passed to a first inlet 22 of engine 34. Air 36 is admitted to the  
35 engine 34 through inlet 32 as well. In one embodiment, the reformat gas 18 is introduced to the air supply line 38 through inlet 40 where it is mixed with the incoming

air 36 before being introduced into engine 34 through inlet 32. Fuel, in the form of diesel or similar, is admitted to the engine 34 through a further injection inlet 42. The gaseous blend containing hydrogen, the air and the fuel is mixed within the engine prior to combustion, thereby allowing operation of the engine. After combustion, the combusted products are discharged from engine 34 through exhaust stream 44 as hot exhaust gases.

In one embodiment, the heated exhaust gases in exhaust stream 44 are passed to heat exchanger 28 where heat is transferred to the incoming water supply 30 to form steam for supply as the steam 12 to reformer 10. The cooled exhaust gases are then vented to atmosphere as cooled exhaust gas stream 46.

A further embodiment of the present invention is shown in Figure 2, where a mixing chamber or similar is provided.

In the embodiment shown in Figure 2, the same reference numerals will be used to identify the identical corresponding features of Figure 1. In Figure 2 there is shown another form of a gas supply system, generally denoted as 4.

This system is the same as that described with respect to that illustrated in Figure 1 apart from having an additional mixing chamber or mixer 60 connected to the air intake supply line 38 of engine 34. In this embodiment, the reformat stream containing hydrogen and other components is conveyed from heat exchanger 22 to a first inlet 62 of mixing chamber or mixer 60 to introduce the gas blend into mixer 60. Air supply 36 is passed through air supply line 38 for introduction through inlet 64 into mixer 60. A further supply line 66 is provided for supplying a mixture of methanol and water 68 to mixer through inlet 70. All of the components of the gas blend 18, the air 36, water and methanol 68 and any other materials are mixed in mixer 60 before being introduced

into engine 34 through inlet 72 for mixing with fuel 42 prior to combustion to operate engine 34. It is to be noted that the gas mixture and air, together with other components of the fuel mixture, are mixed in predetermined amounts to obtain the required ratios. The air is introduced at a constant velocity.

In a still further embodiment of the apparatus and method of the present invention, the hydrogen generator is provided with suitable control means for adjusting the operating conditions so as to produce preselected or predetermined amounts of each of the components of the hydrogen gas, blend or mixture. The ratios of each of the individual components can be adjusted to achieve the desired amounts or ratios.

The advantage of the present invention is that pure or substantially pure hydrogen is not required for efficient hydrogen-assisted combustion. This leads to a great saving in time, effort and expense in not having to remove contaminating material from the hydrogen gas. It is estimated that savings of up to 50 times the current cost of producing hydrogen can be achieved by using the hydrogen in combination with other materials, particularly the other materials produced during the hydrogen gas generation, ie., byproducts of the reaction in the reformer which can be supplied to the engine in combination with the hydrogen in a single feed line or through a single inlet.

In some embodiments of the present invention, the hydrogen gas can be fed directly into the compression engine without having to undergo prior mixing. In other embodiments, the gas can be fed indirectly into the engine by passing through an intermediate component, such as for example, a mixer.

Another advantage of the present invention is that the hydrogen generator can be operated under a wide variety of different conditions to produce a wide variety of different amounts and combinations of components in the

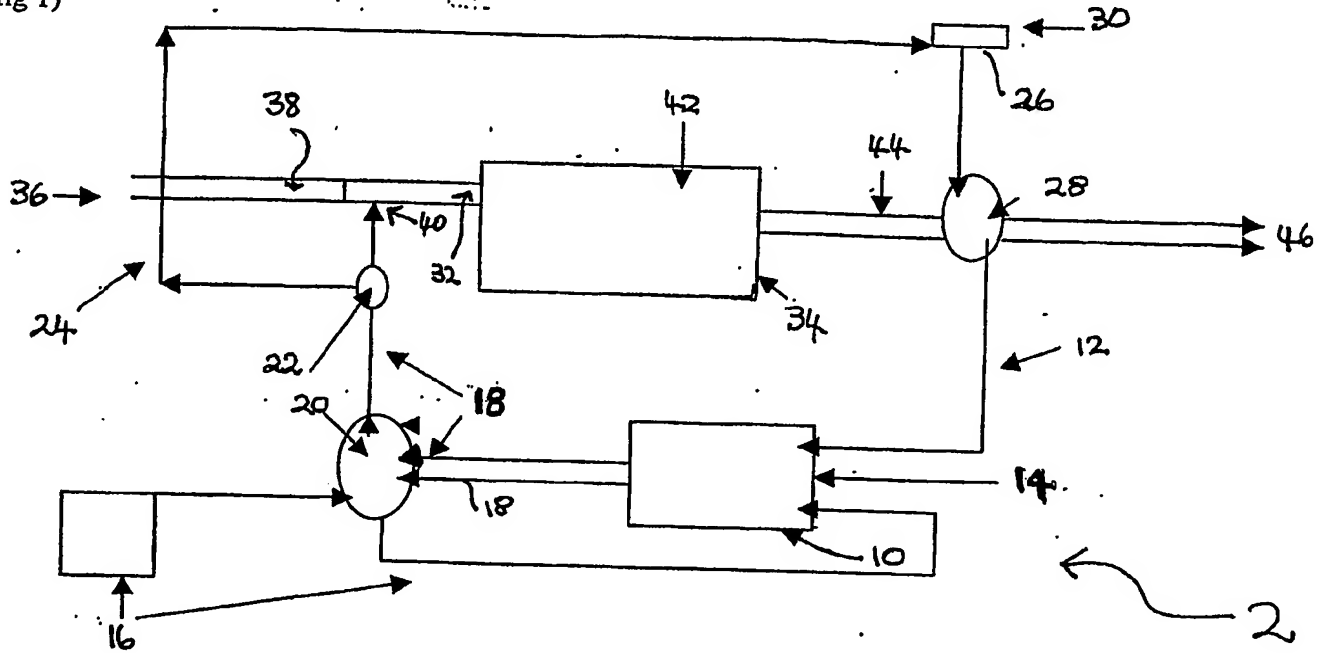
gas blend or mixture in accordance with the requirements of the particular end use, such as for example, in accordance with the size, type and speed of the compression engine.

5        Other advantages of the present invention include that there are fuel savings to be had, that increased power is available and the exhaust emissions are reduced.

10        The described arrangement has been advanced by explanation and many modifications may be made without departing from the spirit and scope of the invention which includes every novel feature and novel combination of features herein disclosed.

15        Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is understood that the invention includes all such variations and modifications which fall within the spirit and scope.

Drawing 1)



Drawing 2)

